TOPIC 19 – REDOX
19.2 – HL ELECTROLYSIS

IB Chemistry

T09D04

Mr. Martin Brakke

19.2 – HL Electrolysis

- 19.2.1 Predict and explain the products of electrolysis of aqueous solutions. (3)
- 19.2.2 Determine the relative amounts of the products formed during electrolysis. (3)
- 19.2.3 Describe the use of electrolysis in electroplating.

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Products of Aqueous Solutions

19.2.1 Predict and explain the products of electrolysis of aqueous solutions.

- In the electrolysis of aqueous solutions, unlike molten, water itself also undergoes electrolysis, complicating the process
  - $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$
    - Each of these ions compete with the dissolved ions
  - In an aqueous solution of NaCl (aq)
    - Positive (H^+ and Na^+) migrate toward the negative cathode
    - Negative (OH^- and Cl^-) migrate toward the positive anode
- Concentrated and dilute solutions will both produce $H_2(g)$ at the cathode, but depending on the solution, the production at the anode may change:

Condition	Anode (+)	Cathode (-)
NaCl is Molten	$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$	$Na^+(l) + 1e^- \rightarrow Na(s)$
NaCl is concentrated	$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$	$2H^+(aq) + 2e^- \rightarrow H_2(g)$
NaCl is dilute	$4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g) + 4e^-$	$2H^+(aq) + 2e^- \rightarrow H_2(g)$

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Electrolysis of solutions

- Follow the rules:
  - Only halides will be oxidized at Anode (otherwise OH^-)
  - Hydrogen is generally reduced at the Cathode

Electrolyte	Electrodes	(-) Cathode ½	(+) Anode ½
KBr (aq)	Graphite	$2H^+ + 2e^- \rightarrow H_2$	**$2Br^- \rightarrow Br_2 + 2e^-$**
$MgSO_4$(aq)	Graphite	$4H^+$(aq) $+ 4e^- \rightarrow 2H_2$(g)	$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$
Conc HCl(aq)	Graphite	$2H^+ + 2e^- \rightarrow H_2$	**$2Cl^- \rightarrow Cl_2 + 2e^-$**
Dilute H_2SO_4(aq)	Graphite	$2H^+ + 2e^- \rightarrow H_2$	$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$
Dilute NaOH(aq)	Graphite	$2H^+ + 2e^- \rightarrow H_2$	$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$
$CuSO_4$(aq)	Graphite	$Cu^{2+} + 2e^- \rightarrow Cu$	$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$
$CuSO_4$(aq)	Copper	$Cu^{2+} + 2e^- \rightarrow Cu$	$Cu \rightarrow Cu^{2+} + 2e^-$
$CuCl_2$(aq)	Carbon	$Cu^{2+} + 2e^- \rightarrow Cu$	**$2Cl^- \rightarrow Cl_2 + 2e^-$**
KI(aq)	Carbon	$2H^+ + 2e^- \rightarrow H_2$	**$2I^- \rightarrow I_2 + 2e^-$**

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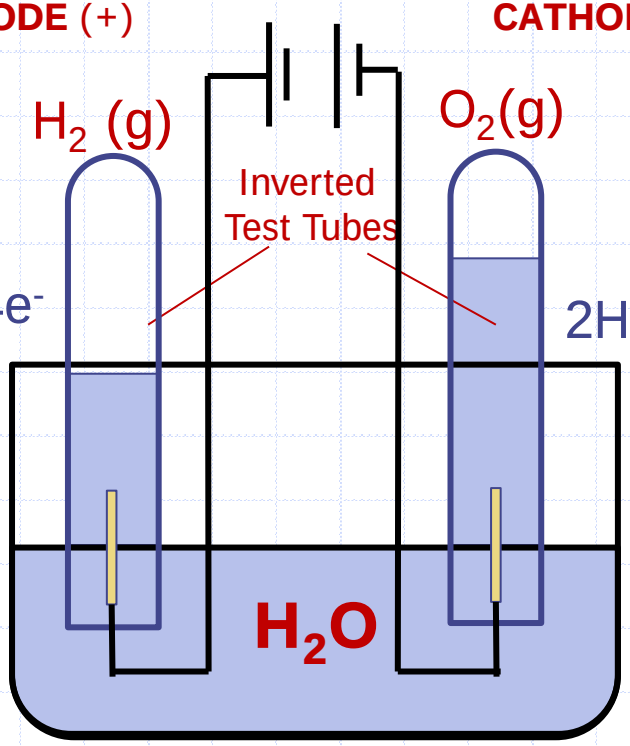
Electrolysis of Water

Flow of Electrons

Positive Electrode **ANODE** (+)

Battery

Negative Electrode **CATHODE** (-)



Oxidation

$2O^{-2} \rightarrow O_2(g) + 4e^{-1}$

$H_2O(l) \rightarrow O_2(g) + 4H^+ + 4e^-$

Reduction

$2H^+ + 2e^{-1} \rightarrow H_2(g)$

$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-$

2:1 Ratio

$H_2 : O_2$

**Must be acidified, H_2SO_4 or other

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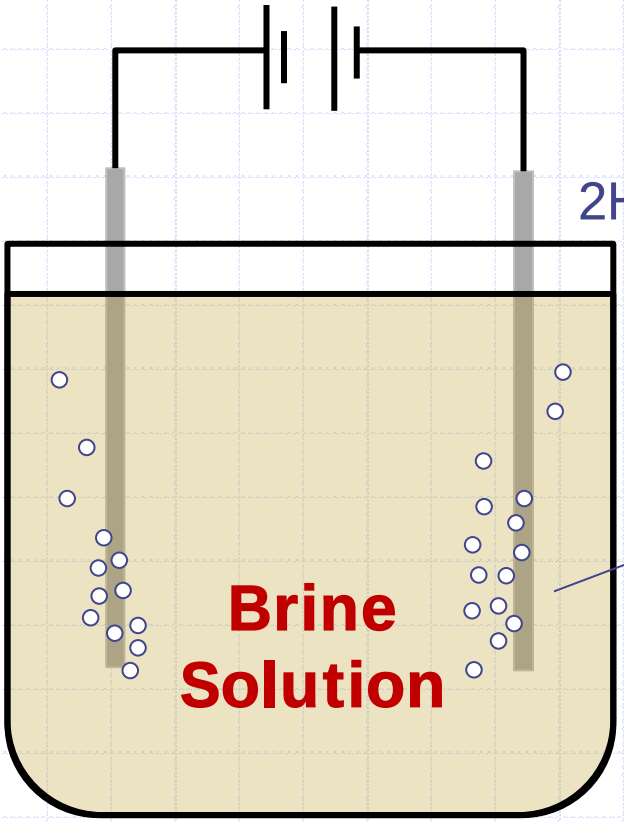
Electrolysis of Brine

Flow of Electrons

Positive Electrode
ANODE (+)

Battery

Negative Electrode
CATHODE (-)



Oxidation

$2Cl^- \rightarrow \mathbf{Cl_2} + 2e^-$

Reduction

$2H^+ + 2e^{-1} \rightarrow H_2(g)$

$2H_2O(l) + 2e^- \rightarrow \mathbf{H_2(g)} + \mathbf{2OH^-}$

Useful raw materials such as Cl_2, H_2, and OH^- are produced and used for a variety of industrial processes

With the formation of OH^- ions, the [NaOH] builds up in the solution making it more basic

Yield of Products

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19.2.2 Determine the relative amounts of the products formed during electrolysis. (3)

- Electrolysis can be used to
  - Extract important metals from lightweight alloys
  - Isolate raw materials from stable compounds such as water and sodium chloride
  - Plate (or cover) a material with another with more ideal properties (to protect, insulate, or otherwise)

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Faraday's Constant

- The amount of material produced through electrolysis is dependent on the current and the amount of time the material is exposed
- The tiny electrical charge on each electron can be expressed in units called **coulombs (C)**.
- The total charge carried by the current:
  - Charge in coulombs (C) = current (A) x time (s)
  - One mole of electrons carries 96,500 coulombs, which is known as **Faraday's Constant**

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Faraday's Laws

- Faraday's First Law:
  - States that the mass of an element produced during electrolysis is directly proportional to the quantity of charged passed during electrolysis
    - The charge (C) is dependent on current (A) and time (s)
- Faraday's Second Law:
  - States that the masses of different elements produced by the same quantity electricity form simple whole number ratios when divided by their relative atomic masses
    - As the masses of each material in any equation just be related through the mole ratio

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Electroplating

19.2.3 Describe the use of electrolysis in electroplating.

- Metals are electroplated to improve performance or prevent corrosion
- Most commonly used metals are Cu, Cr, Ag, and Sn
- In order to obtain a good coating of metal during electroplating
  - The object to be plated must be clean and free of grease
  - The object should be rotated to give an even coating
  - The current must not be too large or the ‘coating’ will form too rapidly and flake off
  - The temperature and concentration of the electrolyte must be carefully controlled, otherwise the ‘coating’ will be deposited too rapidly or too slowly

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Electroplating

The metal you want to use to plate onto another metal is made the anode

Metal to be plated is made the cathode